

APPLICATION UNDER UNITED STATES PATENT LAWS

Invention: **AUXILIARY CODING FOR HOME NETWORKING COMMUNICATION SYSTEM**

Inventor(s): Gang HUANG;
Zhenyu WANG; and
Jinguo YU

Manelli Denison & Selter PLLC
2000 M Street, NW
7th Floor
Washington, DC 20036-3307
Attorneys
Telephone: (202) 261-1000

This is a:

- ☐ [] Provisional Application
- ☒ [X] Regular Utility Application
- ☐ [] Continuing Application
- ☐ [] PCT National Phase Application
- ☐ [] Design Application
- ☐ [] Reissue Application
- ☐ [] Plant Application

SPECIFICATION

AUXILIARY CODING FOR HOME NETWORKING COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

5 1. Field of the Invention

This invention relates generally to telephone devices. More particularly, it relates to a home networking communication system for networking computers within a small environment such as a home.

10 2. Background of Related Art

There has been an explosive growth in the use of telephone lines in many households, driven largely by the need for simultaneous Internet access, voice communications, networking, etc. Many households and small business are already wired with a telephone line,
15 providing the basis for a convenient wired network.

The HomePhoneline Networking Alliance (HomePNA) is an association of leading companies working together to help ensure adoption of a single, unified phoneline networking industry standard and rapidly bringing to market a range of interoperable home networking
20 solutions. With homenetworking, households receive the benefits of simultaneous, shared internet access, printer/peripheral sharing, file and application sharing, and networked gaming. In addition, consumers can enjoy the use of each of these home entertainment and information services using existing wiring in the home.

25 Home PNA 2.0 offers several advantages over older technologies. Like the first-generation PNA, it uses your existing phone lines, but it can operate at speeds up to 32 Mbps. Unlike Ethernet, Home PNA doesn't require a hub; each PC simply connects to the nearest telephone jack, but doesn't interfere with the phone's normal operation.

A home networking system is a communication system used to link home personal computers and home electronic appliances together. The media of the link may be, e.g., telephone line, power line or wireless media. The protocol may be, e.g., Ethernet or other LAN (local area network).

An exemplary home networking system **600** is illustrated in Fig. 9 linking, e.g., a first PC **602**, a washer **604**, a dryer **606**, a second PC **608**, a stove **610**, a video **612**, and an audio device **614**.

Currently, as many as five (or more) services may co-exist on a single copper pair (i.e., telephone line). They are voice band service (POTS), ISDN service, ADSL service, HPNA (Home Phone line Network Alliance) service and VDSL service. HPNA exists within a home on an internal copper pair, the other services are delivered to the home on an external copper pair.

Fig. 10 shows a conventional distribution of spectral regions typically used for various services, e.g., voice services, xDSL services such as ADSL and g.Lite or G.922.2, and of a home network such as HPNA.

As shown in Fig. 10, a single telephone line is shared such that the various services co-exist as a type of FDM (Frequency Division Multiplex) system. In this arrangement, Plain Old Telephone Service (POTS) exists in the 0-4 kHz region, an exemplary xDSL service may be present from 25 kHz to approximately 2.2 MHz (depending on the definition of "x"), and the HPNA spectrum occupies 5.5-9.5 MHz for HPNA V1.x technology or 4.25-9.75 MHz for the emerging V2.x technology.

Fig. 11 depicts the HPNA description of a conventional HPNA compliant transmitter which generates a physical layer (PHY) signal.

In particular, as shown in Fig. 11, an HPNA transmitter **800** consists of a frame processor **802**, a data scrambler **804**, a bit-to-symbol

mapper (i.e., constellation encoder) **806**, and a QAM (e.g., FDQAM) modulator **808**.

The output of the HPNA transmitter **800** is a 4 MBaud quadrature amplitude modulation (QAM) and 2 MBaud Frequency Diverse QAM (FDQAM), with 2 to 8 bits-per-Baud constellation encoding, resulting in a physical layer payload modulation rate that ranges from 4 Mb/s to 32 Mb/s. Information is transmitted on the HPNA channel in bursts, or frames.

Fig. 12 shows the HPNA2.x standard frame **900**, which is based on telephone line and Ethernet protocol.

In particular, Fig. 12 shows exemplary conventional Home PNA network packet frames **900a**, **900b**, including a training sequence (TRN) **902a**, **902b**, a head portion (HEAD) **904a**, **904b**, and a data payload (DATA) **906a**, **906b**.

The training sequence (TRN) **902** is a predefined preamble (e.g., 64 symbols) in each Home PNA network packet frame **900**. The header (HEAD) **904** includes information relating to the source and destination addresses, and the Ethernet type. The data payload (DATA) **906** includes the Ethernet compliant data payload and error checking information.

The Home PNA network packet frames **900** are basic information cells transferring data from one Home network station to another. An Inter Frame Gap (IFG) **920** is between each Home PNA network packet frame **900**. The IFG **920** relates to the silence (no signal) time between two adjacent Home PNA network packet frames **900**.

Fig. 13 shows in more detail the physical layer (PHY) HPNA packet frame format.

In particular, as shown in Fig. 13, each conventional HPNA physical layer frame **900** consists of variable-rate payload information **906** encapsulated by a low-rate header **904** including preamble information **11**,

and a low-rate trailer **1006**. While in the HPNA 2.0 standard the preamble information **11** is defined as being included in the header **904**, it is shown separately in Fig. 13 for ease of description herein.

5 The conventional Home PNA network packet frame format includes an Ethernet compatible sub-frame **930**. This allows Home PNA networking systems to be 100% compatible with current Ethernet devices. Moreover, the use of an Ethernet sub-frame **930** allows the use of existing Ethernet protocol chip sets without the need for redesign.

10 The preamble **PREAMBLE64 11** forms a training period which allows a receiver to train appropriate components, e.g., an equalizer, timing recovery, automatic gain control (AGC), an echo canceler, etc. The **PREAMBLE64 11** is defined as a repetition of four 16 symbol sequences (TRN16) that result from encoding at 2 Mbaud, 2 bits-per-Baud, with the scrambler **804** (Fig. 11) disabled. The TRN16 is a
15 constant amplitude QPSK sequence, designed to facilitate power estimation and gain control, baud frequency offset estimation, equalizer training, carrier sense, and collision detection.

The header **904** includes frame control information **12**, and the initial portion of an otherwise standard Ethernet packet **930**. In
20 particular, the header **904** further includes a destination address (DA) **13**, a source address (SA) **14**, and an Ethernet type **15**.

The frame control field **12** of the header **904** is defined as a 32-bit field as shown in Fig. 14. The frame control field **12** consists of, in the following order, a frame type (FT), scrambler initialization bits (SI),
25 priority (PRI), a reserved field (RSVD), payload encoding information (PE), and a header check sequence (HCS). Also in the header **904**, the destination address (DA) **13** and the source address (SA) **14** are each 24 symbol values, in accordance with Ethernet standards.

The data payload **906** includes the end portion of the
30 otherwise standard Ethernet packet **930**, in particular the Ethernet data

20, a Frame Check Sequence (FCS) **21**, a 16-bit cyclic redundancy check (CRC) **21**, a pad field (PAD) **22** consisting of a number of octets inserted, and an end-of-frame (EOF) sequence delimiter **23** consisting of the first 4 symbols of the TRN sequence from the preamble **11**.

5 Using this conventional approach to Home networking, a predefined preamble **11** of, e.g., 64 symbols, is required before each Ethernet frame to allow synchronization and reliable reception. For instance, the 64 symbols provide time for the receiver to train appropriate components such as an equalizer, timing recovery, an automatic gain
10 controller (AGC), and an echo canceler. However, because the Home PNA 2.0 is a packetized data standard, the receiver must re-train its components for reception of each Home PNA packet network frame **900**. While this is a reasonable approach, it is appreciated by the present inventors to have certain disadvantages.

15 For instance, the training of the equalizer, timing recovery circuits, AGC, echo canceler, etc. during reception of the preamble is commonly referred to as "blind training", meaning that the receiver station doesn't know any information about the incoming signal before it trains its components during reception of the preamble. Thus, the equalizer must
20 be re-trained from scratch for reception of each Home PNA packet network frame **900**. The same for the timing recovery circuits, the AGC, and any echo canceler. Thus, blind training has to accommodate different communication channels and/or different Ethernet types, which significantly impacts performance and/or cost.

25 While the Home PNA 2.0 standard provides a given amount of time, e.g., 64 symbols worth of time, this time is considered by the present inventors to be short, causing 'quickened' training of the appropriate receiver circuits such as the equalizer, timing recovery, AGC, echo canceler, etc., resulting in limited receiver performance.

Another disadvantage is that in HPNA, the Ethernet type includes different baud rates in the DATA period. For each different baud rate, the optimal equalizer training is completely different. So, in the case of blind training, either multiple equalizers must be used, with each
5 equalizer optimally matching each baud rate (increasing cost), or a single equalizer must be implemented which compromises over the different baud rates ultimately reducing performance.

Yet another disadvantage is that in the Ethernet protocol, two adjacent frames may be completely independent, meaning that the
10 two frames may be transmitted from different stations. Thus, their channel properties may be completely different. In this case, the blind training cannot make use of any pre-determined information or any channel information, thus also limiting performance.

There is a need for a technique in home networking
15 communication that permits frame training in a high performance and cost effective manner.

SUMMARY OF THE INVENTION

In accordance with the principles of the present invention, a
20 method of providing advance information to a receiver in a home network comprises providing auxiliary coding to the receiver, and providing data packets to the receiver. The auxiliary coding is associated with data packets on a packet-by-packet basis.

BRIEF DESCRIPTION OF THE DRAWINGS

25 Features and advantages of the present invention will become apparent to those skilled in the art from the following description with reference to the drawings, in which:

Fig. 1 depicts the relevant portion of a Home PNA network
30 device including an auxiliary coding transceiver and a Home network

station pre-training database, in accordance with the principles of the present invention.

Fig. 2 shows an exemplary entries in the Home network station pre-training database shown in Fig. 1.

5 Fig. 3 shows an exemplary insertion of auxiliary coding information into the otherwise conventional training period, together with a shortened preamble, in accordance with one embodiment of the present invention.

10 Fig. 4 shows pulse interval modulation for auxiliary coding in accordance with the principles of the present invention.

Fig. 5 shows the use of BPSK modulation for auxiliary coding in accordance with the principles of the present invention.

Fig. 6 shows the use of FSK modulation for auxiliary coding in accordance with the principles of the present invention.

15 Figs. 7A to 7C show the implementation of auxiliary coding using FSK modulation in both the time domain and the corresponding frequency domain, in accordance with an embodiment of the present invention.

20 Figs. 8A to 8C show the implementation of auxiliary coding using Quadrature Amplitude Modulation (QAM) by code division, in accordance with yet another embodiment of the present invention.

Fig. 9 shows an exemplary block diagram of a conventional home networking system.

25 Fig. 10 shows a conventional distribution of spectral regions typically used for various services, e.g., voice services, xDSL services such as ADSL and g.Lite or G.922.2, and of a home network such as HPNA.

Fig. 11 shows a conventional block diagram of the components of a home networking transmitter.

30 Fig. 12 shows a conventional HPNA frame format.

Fig. 13 shows in more detail the physical layer (PHY) HPNA frame format.

Fig. 14 shows frame control fields in the header of the HPNA frame.

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DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

This invention presents a new idea and approaches to overcome the blind frame-training problem for conventional home networking techniques, e.g., such as the one described by the HomePNA2.x standard. In particular, in accordance with the principles of the present invention, advance training information is provided to a receiving Home network station via auxiliary coding, synchronized and/or included in the relevant Ethernet type packet. The advance training information (e.g., training information resulting from the reception of a previous frame) is referred to herein as "Over Frame Training".

The training information may be, e.g., an early identity of the source of the packet, with a subsequent lookup performed by the receiving station for predetermined training value(s), or the training values themselves may be transmitted to the home network receiver via auxiliary coding.

The present inventors have appreciated that Ethernet information is inside the HEAD 904 of the Home PNA packet network frame 900, which is received after the period of time used for frame training 902. For instance, as seen in the previously described Fig. 13, the source address SA 14 is not transmitted to the receiving home network device until after the preamble 11, the frame control 12, and the destination address 13. This requires 104 symbols to be transmitted before the source address 14 is begun.

Thus, in conventional Home PNA network systems, a receiving station doesn't know anything about the yet-to-be received data

frame until after the training period TRN **902** and significantly into the header information **904**.

5 In accordance with the principles of the present invention, auxiliary coding is used to provide advance information to the receiving home network device sufficient for the home network device to seed one or more trainable components with an appropriate predetermined value (e.g., the trained value for the last frame **900** received from that particular transmitting home network device, a moving average of past frames **900**, etc.)

10 In accordance with various embodiments of the present invention, the auxiliary coding information is transmitted before and/or during the frame training period **902** of the relevant frame **900**. This permits use of predetermined training values specific to the particular transmitter based on past frames **900** received from that same transmitter
15 during the training period **902** for the received signal to be further refined from that determined from the auxiliary coding, resulting in more efficient and more accurate training of, e.g., a receiving equalizer, time recovery circuits, AGC, echo canceler, etc.

20 Thus, with the advance information provided by the inclusion of auxiliary coding as to the source of a current packet frame **900** (or particular training value(s)), frame training on a signal from a transmitting Home network device over a particular radio channel and/or using a particular Ethernet type can be optimized.

25 Fig. 1 depicts the relevant portion of a Home PNA network device including an auxiliary coding transceiver and a Home network station pre-training database, in accordance with the principles of the present invention.

In particular, Fig. 1 shows the inclusion of an auxiliary coding transceiver **160** and a station pre-training database **170** in association

with a home network device **180**, in accordance with the principles of the present invention.

Fig. 2 shows an exemplary entries in the Home network station pre-training database shown in Fig. 1.

5 In particular, Fig. 2 shows a table including a plurality of entries **291-293**. Each entry **291-293** relates to an association of predetermined information **204**, **206**, **208** and/or **210** (e.g., previously performed training results such as from a previous packet received from the associated station **202**).

10 In the disclosed embodiment, the home network device **180** receives a data frame **900** via conventional reception techniques, but also receives auxiliary coding (i.e., a station ID parameter **202**) via an auxiliary coding transceiver (though in another embodiment the auxiliary coding may be received via the conventional home network transceiver but
15 inserted into the otherwise fixed PREAMBLE64). Armed with early and quick information regarding the identity of the transmitting home network device, the receiving home network device **180** performs a table look-up in the station pre-training table **170** to determine one or more training values. Exemplary training values include, but are not limited to, an
20 equalizer start value **204**, timing recovery start value **206**, AGC start value **208**, and/or echo canceler start value **210**.

Fig. 3 shows an exemplary insertion of auxiliary coding information into the otherwise conventional training period, together with a shortened preamble, in accordance with one embodiment of the present
25 invention.

In particular, Fig. 3 shows the replacement of the otherwise conventional initial symbols (e.g., the first 4 to 5 symbols) of the preamble PREAMBLE64, with auxiliary coding **111a**, and the use of a shortened fixed preamble PREAMBLE59 **111b**. Otherwise, the remaining portion of

the home network packet frame remains as conventionally described by, e.g., Home PNA 2.0.

5 The auxiliary coding symbols inserted into the training portion TRN may be transmitted at a relatively slow data rate (e.g., 1 bit per symbol), relieving the receiver from the need for a fully trained equalizer, from a fully adjusted timing recovery circuit, etc.

10 In the disclosed embodiments, only a locally unique identity be transmitted in the auxiliary coding. For instance, 4 bits of information uniquely identifying 16 sources may be sufficient to provide a basis for receiving home network devices to recall previous training information received from the same transmitting home network device.

15 The auxiliary coding information may include only a local identification (e.g., 4-bit ID) of the transmitting home networking device. The auxiliary coded identification information need not be absolute (i.e., it need not be known that the transmitter is a printer, TV, etc.). Rather, a unique identifier locally defined within only the particular receiving home networking device may be sufficient.

20 Alternatively, or additionally, the auxiliary coding information may include particular advance information about the source, e.g., the data mode, the baud rate, the full identification of the transmitting station, coding information, etc.

There are many different ways to implement an independent auxiliary coding signal in accordance with the principles of the present invention. For instance, pulse interval modulation can be used.

25 Fig. 4 shows the use of pulse interval modulation for auxiliary coding in accordance with the principles of the present invention.

In particular, Fig. 4 shows an exemplary auxiliary coding embodiment implementing pulse interval modulation by time division. In the embodiment shown in Fig. 4, the auxiliary coding is provided to the
30 receiving home network device via an independent signal, so it has no

conflict with home network packet frame signal. Thus, the home network communication frames remain 100% compatible with current Ethernet protocol, with the additional, proprietary auxiliary coding providing advance information to the receiving home networking device.

5 Moreover, it is preferred that the frequency bandwidth of the auxiliary coding signal be inside the current home networking frequency bandwidth, so as to retain compatibility with current home network standards (e.g., Home PNA 2.0).

10 Furthermore, it is preferred that the power level of the auxiliary coding signal follows that of the relevant home network packet frame such that current home network standards (e.g., Home PNA 2.0) remain unaffected.

15 In the disclosed embodiment, it is preferred that the independent auxiliary coding be synchronized with the relevant home network packet frame.

 The pulse interval modulation may be accomplished by adding additional pulses before each frame, and coding the information by varying the timing interval between two adjacent pulses **100a**, **100b**.

20 Preferably, the frequency bandwidth of the pulses **100a**, **100b** are the same as or inside the normal frame frequency bandwidth. One way to ensure this is by adding a pulse shaping filter and/or a band pass filter after the pulse generator of the transmitting home network device.

25 Preferably, the pulse amplitude and/or energy level of the auxiliary coding follows the specification of the relevant or associated home network frames. An example of the pulse is the access ID (AID) pulse, which is defined in the Home PNA 2.x compatibility mode.

 The present invention appreciates that although Ethernet standards require 24 symbol long source and destination addresses,

local, much shorter source addresses may be utilized to provide advance information as to the local source of an associated data frame.

Fig. 5 shows the use of BPSK modulation for auxiliary coding in accordance with the principles of the present invention.

5 In particular, Fig. 5 shows an exemplary auxiliary coding embodiment implementing auxiliary data (e.g., a local station ID) coded by BPSK (Binary Phase Shift key) modulation by time division. Auxiliary coding is implemented as an additional sequence before the otherwise conventional home network frame. The auxiliary coding sequence may
10 be transmitted by the same radio frequency (RF) front end as is the Home PNA network frame, preferably with a silence period **500b** inserted between the auxiliary coding (e.g., the BPSK data **500a**) and the Home network data frame **900**.

15 In the disclosed embodiment, it is preferred that the amplitude and frequency band of the auxiliary BPSK coding **500a** follows the specification of the conventional frame, e.g., Home PNA 2.0.

Fig. 6 shows the use of Frequency Shift Keying (FSK) modulation for auxiliary coding in accordance with the principles of the present invention.

20 In particular, Fig. 6 shows an exemplary auxiliary coding embodiment implementing FSK modulation by time division, in place of the BPSK modulation shown in Fig. 5.

Figs. 7A to 7C show the implementation of auxiliary coding using FSK modulation in both the time domain and the corresponding
25 frequency domain, in accordance with an embodiment of the present invention.

In particular, Figs. 7A to 7C show an exemplary auxiliary coding embodiment implementing FSK modulation by frequency division. In Figs. 7A to 7C, the additional FSK modulated signal **600a** (Fig. 6) is
30 mixed into the otherwise conventional home network data frame signal.

As a result, the FSK frequency of the auxiliary coding **100** is located on the two sides of the normal frame frequency band.

Figs. 8A to 8C show the implementation of auxiliary coding using Quadrature Amplitude Modulation (QAM) by code division, in accordance with yet another embodiment of the present invention.

In particular, Figs. 8A to 8C show QAM modulation by code division. Figs. 8A to 8C show exemplary coding implementations of redefined preamble sequences including auxiliary coding inside (e.g., as shown in Fig. 3). In accordance with this embodiment, different transmitting home network stations might use different constellations such as those shown in Figs. 8A to 8C to identify themselves or particular training information.

The baud rate may be increased in the preamble to make room for auxiliary coding information. For example, when the preamble is coded at 2 MBaud, then the auxiliary code may be inserted by coding at 4 MBaud.

One particular advantage provided by the present invention is the ability for faster data rates due in large part to the better training for relevant components. For example, with auxiliary coding in accordance with the principles of the present invention, the equalizer of the receiving home network device may be pre-trained with the trained value from past packets received from the same home network device, allowing additional time to further refine and train on the received signal. The additional time for training the equalizer, timing recovery circuits, etc., leads to the ability to increase the data rate of the signal. For example, the HPNA2.x conforming home network may increase to as much as 30Mbit/sec from the otherwise conventional 20Mbit/sec.

While the invention has been described with reference to the exemplary embodiments thereof, those skilled in the art will be able to

make various modifications to the described embodiments of the invention without departing from the true spirit and scope of the invention.